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# THE CURVE OF FORGETTING\*

By E. O. FINKENBINDER, A. M., Clark University

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### *I. Introduction*

The aim of the investigation reported in the following pages is to trace the course of the curve of forgetting as determined by the lapse of time. Every act of memory has, of course, to do with some remembered content; and within this content it is possible to distinguish at least two factors: 1. A memory image of something which has been perceived; and 2. Certain associative bonds which connect the images with one another and thereby constitute trains and constellations and other more or less unitary groups of contents of consciousness. Both of these factors must be taken into account in any investigation of memory, because a complete sundering of the image factor and the association factor is impossible. In the present investigation we are concerned chiefly with the image. For the purpose of isolating this factor so

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\*The investigation which is here reported was conducted in the psychological laboratory of the University of Illinois. The experiments were carried through by Miss Alida C. Bowler and Mr. Erwin O. Finkenbinder, who were then students in the senior year. On the completion of the experiments, Miss Bowler turned over her data to Mr. Finkenbinder who has assumed the responsibility of preparing this paper for publication.

J. W. BAIRD.

far as possible, we have chosen nonsense syllables as our material. We may study the image phenomena in still purer and more isolated form by the use of evidence furnished by the introspections of our observers. Therefore, our results and the inferences which they justify have to do with the processes of memorizing and recalling in which the association factor is reduced to a minimum and the image factor is raised to a maximum.

## II. History of the Problem

The first experimental investigation of the rate of forgetting was undertaken by Ebbinghaus,<sup>1</sup> in the years 1879-80 and 1883-84. He attempted to discover the rate of forgetting meaningless material and also significant (meaningful) material during the first thirty days after it had been learned. His nonsense material consisted of meaningless single syllables, while his significant material was made up of selections of prose and poetry. Ebbinghaus himself served as both observer and experimenter in this investigation. He first prepared a great variety of nonsense syllables, each syllable being constructed by inserting a vowel or diphthong between an initial and a final consonant. Each of these syllables was written upon a small card and the cards were shuffled so that the syllables would occur in random order. Each series of twelve syllables was read at the rate of four-tenths of a second per syllable; and after a pause of fifteen seconds a second reading was begun. The successive readings were continued until the learner found that he was just able to recite the complete series correctly. Permanence of retention was tested by means of the "saving method," i. e., after an hour, a day, or a week had elapsed, a given series was relearned; a comparison of the length of time which was necessary for the original learning and for the relearning furnished a means of measuring how much of the original series had been forgotten during the hours, the days, or the weeks which had intervened between the original learning and the relearning. By this means he made a quantitative determination of the amounts that had been forgotten during the following intervals: 19 minutes, 65 minutes, 8 hours, 1 day, 2 days, 6 days, 30 days. His results show that the curve of forgetting assumes a most remarkable form. For-

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<sup>1</sup> H. Ebbinghaus. *Ueber das Gedächtnis: Untersuchungen zur experimentellen Psychologie*, Leipzig, Duncker und Humblot. 1885. 1-188.

getting proceeds very rapidly during the first twenty minutes after learning. And, indeed, more than one-half of the material learned is forgotten during the first hour. The subsequent deviation in the curve is gradually much less abrupt until, after a day has elapsed, its course becomes approximately parallel with the axis.

Other psychologists were instigated to investigate the problem of forgetting with different sorts of materials. Wolfe<sup>2</sup> employed tones and made determinations for intervals up to 120 seconds. Lewy<sup>3</sup> worked with visual extents and determined how well they could be recognized through intervals up to 60 seconds. Bigham<sup>4</sup> chose words, letters, colors, and numbers; and intervals of 2, 10, and 30 seconds. Baldwin and Shaw<sup>5</sup> used simple geometrical forms, and determined the impairment of memory at the end of 10, 20, and 40 minutes. In all these investigations and in numerous others which need not be cited here, the work was more limited, at least in regard to amount of material and lengths of intervals, than in the pioneer work of Ebbinghaus; but, so far as they go, they all confirm in general the findings of Ebbinghaus. Thus it appears that the temporal course of the process of forgetting is essentially similar for a great variety of memorial materials,—nonsense syllables, tonal pitches, visual lengths, geometrical areas, colors, numbers, letters and significant words. Yet it is to be noted that these later investigations deal with relatively brief intervals,—seconds and minutes; the determinations made by Ebbinghaus were for longer periods of time, ranging from nineteen minutes to thirty days.

A second investigation of the problem to determine the progress in learning and forgetting nonsense syllables was undertaken by Müller and Schumann.<sup>6</sup> In this investigation the observer was in no way concerned with the act of presenting the syllables. Moreover, the order of the syllables themselves within a given series was carefully arranged; by this means

<sup>2</sup> H. K. Wolfe, Untersuchungen über das Tongedächtnis. *Philosophische Studien*, III, 1896, 534-571.

<sup>3</sup> W. Lewy, Experimentelle Untersuchungen über das Gedächtnis. *Zeitschr. f. Psychol.*, VIII, 1895, 231-292.

<sup>4</sup> J. Bigham, Memory. *Psychol. Rev.*, I, 1894, 34-38; 453-461.

<sup>5</sup> J. M. Baldwin and W. J. Shaw, Memory for Square Size. *Psychol. Rev.*, II, 1895, 236 ff.

<sup>6</sup> G. E. Müller und F. Schumann, Experimentelle Beiträge zur Untersuchung des Gedächtnisses. *Zeitschr. f. Psychol.*, VI., 1894, 81-139; 257-339.

it was possible to eliminate the variable influence of alliterations, consonances, and the like in successive syllables. The syllables were presented by means of a rotating drum which enabled the experimenter to keep the temporal conditions of presentation constant. The results of Müller and Schumann confirmed the findings of Ebbinghaus in so far as they bore directly on the curve of forgetting, but these were very limited. They found that the amount of forgetting was less than Ebbinghaus had reported.

Radossawljewitsch<sup>7</sup> attacked the problem anew in 1903-04. He employed more learners,—fourteen men and four women between the ages of twenty and forty, and six boys and five girls between the ages of five and thirteen years. His method was essentially identical with that employed by Müller and Schumann, excepting that he introduced the factor of accentuated rhythm into the act of learning the syllables. His findings differ from earlier investigators, 1, in that the rate of forgetting is slower, and 2, that it is not uniformly progressive. The most prominent irregularity in his curve consists in an enormous deviation at the end of the eight-hour interval; indeed, he found that more had been forgotten at the end of eight hours than at the end of a day or even two days. It was partially in the hope of finding an explanation of this remarkable and irregular state of affairs that the present investigation was undertaken.

### III. *Our Own Experiments*

#### A. Materials, Apparatus, Procedure, Observers, Differences Between our Method and Those of our Predecessors

Our materials consisted of nonsense syllables which were constructed in the following fashion. We first wrote out lists of all of the possible combinations of three letters containing each vowel between an initial and a final consonant. Thus, one list began with *bac, bad, baf, bag*, etc., another list contained *bec, bed, bef, beg, beh*, etc. Each of the five vowels being thus combined with every possible pair of consonants gave a total of 2,205 syllables. This long list of syllables was now censored with great care, independently by several readers, and every one which strongly suggested a meaning was eliminated; for instance, of all the syllables which are cited in the above illustrations, only one, *beh*, escaped elimina-

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<sup>7</sup> Paul R. Radossawljewitsch, *Das Behalten und Vergessen bei Kindern und Erwachsenen*. Leipzig. Nemnich, 1907. 197 pp.

tion, and was employed in the investigation. Approximately one thousand syllables were left after this process of elimination was completed; and these were combined into groups of twelve each, care being taken throughout to avoid alliterations, consonances, recurrence of the same initial or final consonant in successive syllables, and the like. An effort also was made so to constitute the groups that each series of twelve presented about the same degree of difficulty for the act of learning. It is, of course, impossible to find any combination of three letters which shall be wholly unmeaning to all learners. But it is possible, by the exercise of care, to construct groups of syllables which shall present an approximately uniform degree of difficulty of memorization throughout, and in which the factor of familiar association is reduced to a minimum. And the fulfilment of these two conditions seemed to be sufficient to provide the proper material for our investigation.

The letters which we employed were made of black paper, 3.3 cm. in height and 2.8 cm. in width, and were pasted, in groups of three, upon sheets of white cardboard 12 cm. wide and 18 cm. long. The twelve cardboard sheets which carried the syllables of each group were then bound into booklets by means of adhesive tape; and the pages of this booklet were then cut or "indexed" across the top in such fashion that the experimenter could readily turn the pages one at a time. A metronome in a sound-proof box, audible to the experimenter alone, marked off the time interval which should elapse between the successive presentations of the syllables of a series. The booklet stood in a convenient position upon a table; and the experimenter turned a page, thereby exposing a syllable, every two seconds,—each syllable appearing immediately after the disappearance of the preceeding syllable, and remaining in view for a period of two seconds. This procedure was continued without interruption until the observer found that he was just able to predict the syllable which was about to appear; this criterion had been adopted by the experimenters as an assurance that the learning of each series had been brought to a uniform level of completeness at the instant when the act of learning ceased and the process of forgetting presumably began. A record was kept of the number of presentations which was necessary to produce this memorial effect. This same series of syllables was relearned in like manner after a definite interval,—30 minutes, 1 hour, 2 hours, 4 hours, 8 hours, 12 hours, 16 hours, 24 hours, 36 hours, 48 hours, or 72 hours; and a comparison

of the number of repetitions required in the two cases enabled us to determine the amount that had been forgotten. In order to discover and to make allowance for the diurnal variations in ability to learn, the learning times for each observer were distributed throughout the day, as follows: 8 A. M., 11 A. M., 2 P. M., 5 P. M., 8 P. M. (11 P. M. in a few cases of especial interest).

No attempt was made to impose any particular or uniform method of learning upon our observers. Each was permitted to employ his own natural method, but was warned not to change his procedure during the course of the investigation. After each act of learning, the observer gave a detailed introspective account of the act of learning; these introspections not only afforded an insight into the mental processes involved, which will be mentioned in a later section, but they also constituted a control in that they revealed any deviation from the original natural procedure in learning. The observers gave no further voluntary attention to the syllables until the desired interval of time had elapsed, when they made a brief recall to determine how many they could freely reproduce. They then relearned in the same manner as before, continuing the process of learning to the point where they just succeeded in predicting each syllable before it came into view.

The observers, four women and ten men, who served throughout the year, were: (1) S. Carolyn Fisher, graduate student in psychology; (2) Alida C. Bowler, senior, psychology; (3) Sarah Rogers, junior, languages; (4) Amy Overland, freshman, literature and arts; (5) Howard F. Swits, senior, psychology; (6) Oliver L. Herndon, senior, psychology; (7) Claude E. Burgener, senior, psychology; (8) Erno B. Pletcher, junior, literature and arts; (9) Erwin O. Finkenbinder, senior, psychology; (10) Jacob Sinclair, junior, science; (11) Lyle J. Pletcher, freshman, science; (12) J. Elmer Wiley, special, agriculture; (13) Royal R. Finkenbinder, special, agriculture; (14) Louis Seyster, academy.

Former investigations which deal with exactly the same problem of forgetting differed from our own in the following particulars:

1. Our observers were fourteen in number; Ebbinghaus had but a single observer, himself.

2. An experimenter presented the material; this avoided the distraction which necessarily occurs when the observer

presents his own material. Ebbinghaus presented his own material to himself as observer.

3. Our materials were nonsense syllables; and our groups of syllables were carefully prepared with a view to avoiding alliteration, consonance, rhyme, etc., which would serve as associative bonds to the learners. This precaution Ebbinghaus failed to observe, in that he shuffled his syllables in constructing a series.

4. Our observers were allowed to follow their own methods of learning; but they were cautioned to avoid grouping the syllables, to avoid looking for associations, and to avoid changing their method during the course of the investigation. Radossawljewitsch prescribed a method of learning,—which employed an accentuated rhythm throughout. Ebbinghaus employed an arbitrary but varying accent in reading.

5. We first gave series for preliminary practice in order to familiarize the observers with their part of the work, and to bring them to such a level of efficiency that the increase of efficiency<sup>9</sup> in learning would be slight as the experiment progressed. Radossawljewitsch did not take this into account, although he found that in the later sittings the act of learning was accomplished in about one-third of the length of time which was required in the earlier sittings. (See p. 22 of this paper.)

6. Our observers read and re-read the syllables continuously until all were learned,—each syllable being present to vision two seconds each time. Ebbinghaus, Müller and Schumann, and Radossawljewitsch introduced a pause after each series had been read through. They also required a recall or reproduction when the observer thought that he was able to repeat all the syllables in the series, and then a second recall as an assurance that the learning had been complete.

7. Eleven different intervals between learning and relearning were included in our investigation. Seven of these furnished determinations for points within the first twenty-four hours of the curve, while Ebbinghaus and Radossawljewitsch made determinations for only three and four points, respectively, within this same span.

8. In order to neutralize the results of practice, which may increase the efficiency of the learner as the experiment

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<sup>9</sup> A curve of the gain in efficiency throughout the experiment is given on p. 22, which indicates that no marked change in efficiency occurred during the progress of those experiments whose results are included in our table.

progresses (i. e., even in the experiment proper, after the preliminary practice period) these intervals were investigated at sittings which were distributed regularly throughout the whole year's experimentation. Radossawljewitsch failed to regard this fact; he first tested the five-minute period, second the twenty-minute, third the one-hour period, etc.

9. Between successive determinations a period of eight hours or more was allowed to pass, so as to avoid confusion between syllables presented at different sittings. Radossawljewitsch gave three new series each day.

10. To prevent the effects of diurnal variations of bodily and mental condition,—fatigue and the like,—from falling at any one place in the curve, the periods for learning for each observer were distributed uniformly throughout the day. Ebbinghaus distributed his learning time throughout the day as follows: 10 A. M., 11 A. M., 1 P. M., 6 P. M. Radossawljewitsch did not take sufficient precautions to eliminate the variable influence of diurnal variations of general efficiency, with the result that in the case of the eight-hour interval the determination of amount forgotten was always made in the late afternoon, a feature which was characteristic of only this interval. A further discussion of this point appears on p 28.

## B. Results, Quantitative and Qualitative

### 1. Methods of Learning, Recalling and Relearning

Various methods of procedure were followed by the different observers. It appears, however, that three observers, numbers (5), (8) and (12) of the above list, fall into one class. They gaze intently at the syllables while learning them,—as they express it, they “just look at them.” But at times even these three report that they “think them over and over, saying them in imagination” while looking at them. One observer (8) prefers to take just a glance at the syllable and then turn away, picturing it in space and retaining it, continuously if possible, as a visual image. He recalls in terms of visual imagery, for at times he knows the general shape of the syllable, but is not sure whether the letter is H or K, or even B; he knows that it is not Q or C, since the shape is very different. He remembers a “full syllable” opposed to a “thin” one, as MUB opposed to YIL. Occasionally, when he tries to learn a difficult syllable, he probably vocalizes it, although he says that he “thinks it over

and over visually." Vocalizing, however, for him is very rare, for he clings to one type of imagery more exclusively than does any other of our observers. A sheet of original data which shows the kind of work that is typical for him, follows:—

*Observer No. (8).*

Series No. 41. Initial learning at 8 P. M., Jan. 27.

Learning,—ten presentations of each syllable.

Relearning,—after 72 hours, six repetitions.

*Introspection,—*

"The syllables were not learned by grouping; they were learned individually. The first one 'stuck' on the first time through, then the next one was associated with it, and each to the one preceding. The last two or three came together after about the fifth time. The syllables seemed to 'stick' just by looking them over. I looked at them until I could see them in imagination before they came into view."

Introspections show that another of these three (5) at times articulates the syllable silently. Seldom does he move his lips while learning, and only when learning a difficult syllable. His procedure consists in staring at the syllable before him. After looking at each a few times, one or more are known; and from this time on he spends a part of the time in trying to bring up a visual picture of the forthcoming syllable. Near the end of the learning, the time is mostly spent in attempting to recall the syllable which is to follow. Finally he is able to image them all visually before they come into view.

The other of the three predominantly visual learners (12) says, "I just look at them," yet he, too, has at times repeated them, moving his lips, and thus can not be using visual imagery alone, as a method of learning. In recall, he has never been able to discover any but visual images.

Observers (11) and (13), on the contrary, prefer to repeat the syllables in a whisper or aloud. They say, for instance, QIJ, QIJ, QIJ, QIJ, while the syllable is before them; and when XAC appears, they say, XAC, XAC, QIJ, XAC, XAC; then while the next one is before them, they say, QIJ, XAC, SOH, SOH, SOH, then, SOH, VIG, SOH, VIG, VIG, etc., in varying time and emphasis. These two then employ mostly the vocal-motor image in learning. Their recall in many cases shows that the syllable comes again to them by means of vocal-motor images, but at times together with auditory and visual images, as the following shows. Introspection at recall, 36 hours after learning is: "Could get them better

by pronouncing them. The associations of the sounds seemed to help somewhat." Another statement of the same observer (11) at recall after a 24-hour interval is: "Relearning is easy because I can almost recall the whole series, some syllables being on 'the tip of my tongue,' but I cannot write them down." The other of these two observers (13) "articulates" the syllable in recalling it. He is never sure whether C or S had appeared in the syllable, when they may be pronounced alike. For example, he reports: "It is SEV or CEV, but I cannot decide which one." This observer in recording his reproductions never prints the syllables in large capital letters, as do the more dominantly visual observers. The latter say that after seeing their own printed syllables their assurance is greater than when the syllables are present only in imaginal form.

The author (9) employs mostly motor but very often auditory images in recall as well as in learning. "I predicted visually the second syllable with uncertainty, and tested it quickly to ascertain whether the feeling of saying it would make me certain of the vowel. It did. First, I tried to say MIR, but that did not feel right, then the syllable came easily and I knew it was correct,—MUR." The high-pitched sound of YIK, NIQ, TIJ, is contrasted with the round and empty sound of YOG, BOQ, PUV, GUB, etc. However, M and H are usually visual images in recall, and they are remembered sooner than many other letters, and with greater certainty.

Observer (2) repeats or vocalizes the syllable, and vocalizing appears to be almost as prominent in each of the other women observers. One of the women (3) reports that she most often repeats (vocally) the syllables before her in order to learn them, yet she has often given emphasis to the visual image. In some cases she reports that she just looks at the syllables and learns them so that they all appear in visual imagery.

Another observer (1) has particularly associative methods of learning. She uses auditory and motor imagery chiefly, and the associations are built upon similarities of sound between nonsense syllables and familiar words. She reports many instances of associations which seem to be far-fetched, but which came to her in a most natural and involuntary manner; for instance, HOQ suggests HONESTY, and PUV becomes PULVERISE. There are plainly auditory associations, e. g., LOZ is associated with and remembered by the word LAWS, and YOG by JOG. As many as eight associa-

tions have been recorded in her introspection on learning and recall of a single series. The associations seem very effective to her as a means of recall and almost as effective in learning.<sup>10</sup>

Our learners may then be classified as follows: 1. The silent visualizer, the learner who just gazes at the syllables; 2. the active vocalizer, the learner who actually speaks the syllables in a whisper; 3. the vocalizer and visualizer, the learner who uses the motor image and the visual image correlatively; (this type Radossawljewitsch did not find among his observers; but he rather encouraged the use of the auditory and motor image by the employment of rhythm in presentation); 4. the vocalizer and auditor, the learner who images the sound of the syllable as well as its pronunciation; and 5. the vocalizing auditory-associator, the learner who formed many associations with words, and then remembered these by auditory and motor images. The images which each observer employs are chiefly of one sort throughout, although no observer uses any one sort exclusively; and every observer has at times employed vocal motor imagery, and similarly, visual imagery. Several of our observers use such a variety of images that it is very difficult to determine which modality is most prominent, and it might be well to classify them as belonging to the "balanced" type.

Variations in amount and accuracy of recall have proved to be many times greater than variations in length of time necessary for relearning. At times when the observer was mentally alert and vigorous, many more of the syllables could be recalled than when he had become fatigued. The quantitative results of the recall experiments will not be included in this paper because of their great variability.

When incorrect syllables had been written during the recall test, there was, in many instances, a strong tendency to introduce them into the series during the subsequent relearning, which slightly hindered the process of learning. It sometimes happened that correct syllables were not recognized when they were reproduced during the recall test; they seemed to the observer to be imagined and not remembered. In a few cases, syllables were not recognized even when presented

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<sup>10</sup> Recourse to the factor of association which was so frequently reported by this observer was almost invariably absent in the case of every other observer. And it is interesting to note that this observer's process of retention follows, in general, the same temporal course as that of the other observers, although it occupied a slightly higher level throughout (3 to 5 per cent.).

for relearning, but this was exceptional; almost invariably they were more or less familiar.

We find that the order of the syllables in the series was recalled with greater certainty than the syllables themselves. The order was not always learned before the syllables; and this gave rise to a frequent error of anticipation. Often during the learning, a certain syllable, more clearly known than others near it in the series, was expected to appear several syllables before it did. Our findings regarding the order in which the twelve syllables of the series were learned agree with the results of other investigators: the initial and final syllables of the series were the first to be mastered; the central section of the series, usually the seventh or eighth syllable, was the last to be learned.

## 2. The Value of Various Methods, and Other Comparisons

The differences in method of learning and in ideational type, which have been noted above, do not appear to be responsible for much variation among the curves of forgetting for the various observers, except in the case of the observer who formed meaningful associations. This variation was only 3 to 5 per cent. Radossawljewitsch has shown that there is an average difference of about eight per cent. in the memory of nonsense and meaningful material; and from his results we should expect that this observer (1) would remember more than those observers who attached no meanings to the syllables. Only a few meaningful associations were noticed by the other observers; and, of course, the influence of a very limited number of associations is slight. If, however, the learner should make frequent use of associative connections, the influence of such a procedure would make itself felt upon the tenacity of retention. For this reason we have taken the liberty of discarding certain of our results, basing our selection upon the following principle. When it was found that more than three associations had appeared during the act of learning or relearning, the results obtained were not included in our computations.

Our data do not furnish a basis for the comparison of memory for associated nonsense syllables with memory for monosyllabic words; but if we compare the percentage of associated nonsense syllables remembered (our results) with Radossawljewitsch's curve for memory of monosyllabic words, we find that approximately the same percentage of

significant words and of associated nonsense syllables is remembered. Nor are our data sufficiently extensive to warrant a conclusion regarding the relative memorial efficiency of fast and slow learners, or of men and women. Table I shows, however, that the four most rapid learners,—whose learning times, in seconds per series, averaged 207, 208, 225, and 229 respectively,—are a woman, a man, a woman, a man. The memorial efficiency of these four observers is approximately two per cent. greater than the memorial efficiency of the four slowest learners of our group, whose learning times were 375, 297, 282, and 264 seconds respectively, and whose ideational types are as non-uniform as those of the first four. We have classified the rapid and the slow learners, respectively, in the order given above, as vocalizer, visualizer, vocalizer, visualizer, and as auditor, vocalizer, visualizer, visual-vocalizer. These correlations do not justify the inference that the use of any type of imagery without modification is superior to another. The auditor, the slowest learner, has remembered quite as well as the vocalizer, the most rapid learner. The visualizers (3) and (5) who proved to be fast and slow learners respectively possess approximately the greatest and the least memorial efficiency among our observers. Memorial ability is not clearly correlative with rapidity of learning, with ideational type, or with sex.

### 3. The Effect of Time of Day Upon Rate of Learning

Time of day has a marked effect upon the learning of many of our observers. While three observers are about equally efficient at all times of day, others come with vim and vigor in the morning but become dulled before noon and do not regain their alacrity during the afternoon or evening. Two observers manifest two maxima of efficiency,—at eight o'clock in the morning and at eight in the evening. One observer does his most rapid work at two in the afternoon, but most of them do best at eight o'clock in the morning. The grand averages for all observers show that the most rapid work is done at eight o'clock in the morning, and the least rapid at five o'clock in the afternoon; an average of 13 per cent. more time is required to learn a series at five o'clock in the afternoon than at eight o'clock in the morning. The average length of time required by each observer for the act of learning a series at each of the five periods of day is given in Table I.

TABLE I. RATE OF LEARNING AT DIFFERENT TIMES OF DAY

THIS TABLE SHOWS THE AVERAGE TIME, EXPRESSED IN SECONDS, WHICH EACH OBSERVER REQUIRED FOR LEARNING, AT EACH OF THE FIVE DIFFERENT HOURS OF THE DAY. EACH NUMBER IN THE TABLE IS THE AVERAGE OF EIGHT INDIVIDUAL FINDINGS. THIS TABLE CONTAINS RESULTS FROM ONLY TWELVE OF OUR FOURTEEN OBSERVERS,—THE OTHER TWO DID NOT FURNISH THE FULL COMPLEMENT OF SITTINGS FOR EACH OF THE FIVE TIMES OF DAY. THE MOST FAVORABLE TIME OF DAY FOR EACH LEARNER IS INDICATED BY AN ASTERISK IN THE APPROPRIATE COLUMN.

<i>Observer</i>	<i>8 A.M.</i>	<i>11 A.M.</i>	<i>2 P.M.</i>	<i>5 P.M.</i>	<i>8 P.M.</i>	<i>Average</i>	<i>M.V.</i>
1	230	246	347	...	224*	261.7	42.7
2	173	192	192	312	170*	207.8	41.0
3	236	233	228	225*	229	230.2	3.6
4	200*	240	216	...	246	225.5	17.7
5	269	304	282	309	248*	282.4	19.3
6	301*	341	437	432	367	375.6	39.6
7	300	252*	336	300	298	297.2	18.1
8	228	222	220*	227	252	229.8	8.4
9	259	281	266	271	258*	267.0	9.2
11	280	259	234*	295	252	264.0	18.8
12	197	197	161*	229	259	208.6	28.6
13	264	266	244*	278	242	258.8	12.8
Average	244.8*	252.8	263.6	277.7	253.8	259.9	21.7

#### 4. The Effect of Practice Upon Learning

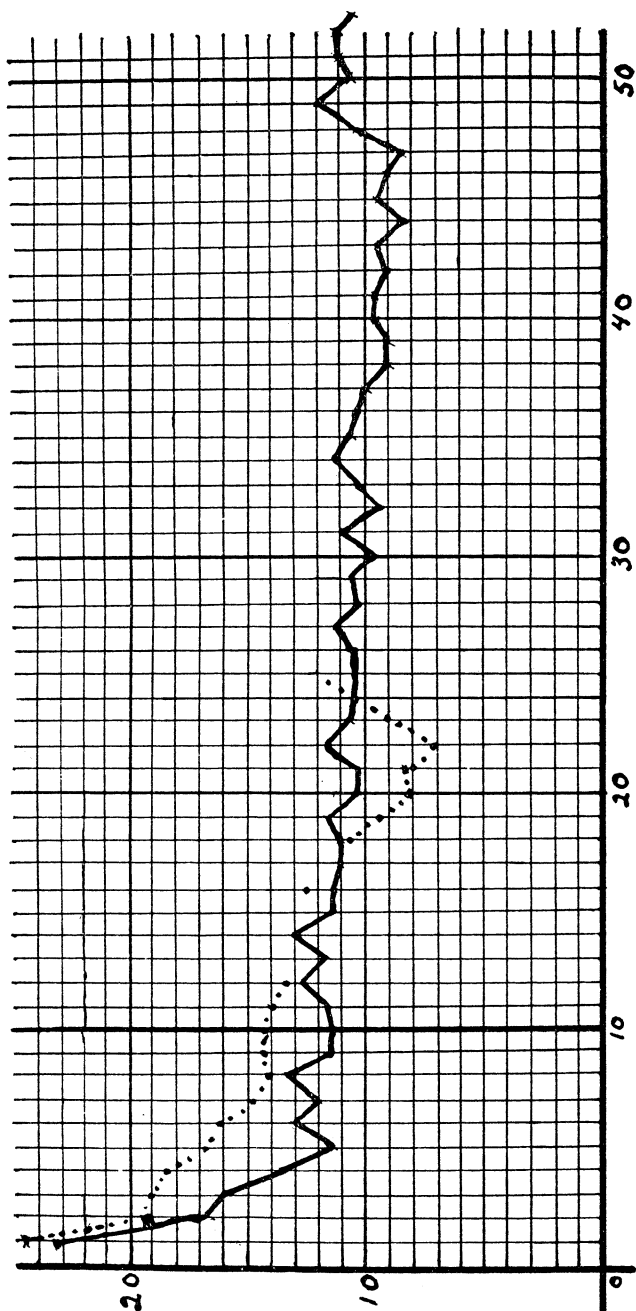
In Plate I, the continuous line shows the average number of presentations required for learning at each sitting throughout the present investigation. The extremes for the first sitting are 13 and 32 repetitions, the average 23.3. The extremes for all single readings after the tenth sitting are 7 and 16 presentations. Most of the gain in efficiency occurs during the first ten sittings. The writer feels that these initial experiments should be regarded as preliminary practice; accordingly these initial results are not included in our computed averages. The dotted line represents the curve of practice as plotted from the results of Radossawljewitsch.

#### 5. The Final Quantitative Results, Showing the Curve of Forgetting

The table below shows the amount forgotten, the averages computed from the results of fourteen observers. The percentages express the ratios of the time spent in relearning to the time spent in first learning. When the observer

PLATE I.—EFFICIENCY IN LEARNING, SHOWING THE EFFECT OF PRACTICE

The continuous line is the curve of the present investigation (fourteen observers); the dotted line that of Rad-  
 ossawljewitsch (eight observers). The ordinate shows the average number of repetitions required for learning a series.  
 The abscissa shows the numerical order of the series.



required twelve repetitions of the series for the first learning and four repetitions for relearning, the ratio of the time for relearning to the time for first learning is 33.3 per cent., which we assume to be approximately the percentage forgotten. If the observer had required twelve repetitions for learning and twelve for relearning, the percentage forgotten would be 100; but if six repetitions had been necessary for relearning, the percentage forgotten would be 50. This method of computation was employed by earlier experimenters and is well understood.

TABLE II. THE AMOUNT FORGOTTEN AFTER THE LAPSE OF DIFFERENT INTERVALS OF TIME

THIS TABLE SHOWS THE RESULTS OBTAINED BY RADOSSAWLJEWITSCH, BY EBBINGHAUS, AND BY THE PRESENT INVESTIGATORS. THE NUMBERS REPRESENT THE AMOUNTS FORGOTTEN, EXPRESSED IN PER CENTS.

Length of Interval	Results of the present Investigation			Results of Radossawljewitsch		Results of Ebbinghaus
	Nonsense Syllables			Nonsense Syllables	Meaningful Material	Nonsense Syllables
	Ave. <sup>11</sup>	P.E.	$10 (\log t + 1)$ <sup>12</sup>	Ave.	Ave.	Ave.
5 Min. . . .	....	...	16.9	2.5	....	....
20 " . . . .	....	...	23.0	11.4	3.9	41.8
30 " . . . .	25.0	1.3	24.7	....	....	....
1 Hour. . . .	27.2	.6	27.7	29.3	21.7	55.8
2 Hours. . .	30.6	1.8	30.7	....	....	....
4 " . . . .	33.6	1.7	33.8	....	....	....
8 " . . . .	34.5	1.4	36.8	52.6	41.9	64.2
12 " . . . .	36.2	1.4	38.5	....	....	....
16 " . . . .	37.0	.9	39.8	....	....	....
24 " . . . .	42.2	1.8	41.5	31.1	20.3	66.3
36 " . . . .	41.2	1.9	43.3	....	....	....
2 Days. . . .	44.5	1.8	44.5	39.1	33.2	72.2
3 " . . . .	47.9	1.7	46.3	....	43.5	....
4 " . . . .	....	...	47.6	....	45.5	....
5 " . . . .	....	...	48.5	....	43.5	....
6 " . . . .	....	...	49.3	50.7	57.6	74.6
7 " . . . .	....	...	50.0	....	50.0	....
14 " . . . .	....	...	53.0	59.0	70.0	....
21 " . . . .	....	...	54.8	62.2	52.4	....
30 " . . . .	....	...	56.3	79.8	76.1	78.9
120 " . . . .	....	...	62.3	97.2	....	....

<sup>11</sup> These numbers are the averages of our fourteen individual curves; and each point in the individual curves, from which these are computed, is the average of five tests, except in the cases of 8, 12, 16, and 36-hour intervals, for which the relearning time of one or more of the desired determinations fell between midnight and six o'clock in the morning. The mode, the median and the average almost coincide throughout.

<sup>12</sup> The general formula may be stated, using  $k$  and  $c$  as constants,

## IV. Discussion

The curve which expresses the results of our investigation shows a greater percentage retained than the Ebbinghaus curve, but less than the curve of Radossawljewitsch. Under the conditions employed by Radossawljewitsch or by the experimenters at the University of Illinois no observer has shown so great an amount of forgetting as did Ebbinghaus. The fact that he was observer and experimenter at the same time is unfavorable for obtaining the best results. And the fact that he presented his material at an exceedingly rapid rate may, in view of his unusual experimental conditions, have constituted a second cause of variation between his findings and our own.

That the Radossawljewitsch curve shows much less forgetting than the curve yielded by the present investigation is

$t$  the time in minutes, and  $\log$  the common logarithm: the amount forgotten equals  $k(\log t + c)$ . The Ebbinghaus formula is

$$100 - \frac{(log t)^c + k}{100}$$

Piéron (H. Piéron, Les courbes d'évanouissement des traces mnémoniques. *Compt. Rend. Acad. d. Sc. Par. CLII., 1911. 1115-1118*) has given a formula for the pond-snail,—

$$100 - \frac{k (log t)^\alpha}{t^\beta}$$

But his curve can not be compared with ours because he has not allowed for the effects of practice; and in his brief test to see if this curve applies to humankind, employing 50 ciphers as his material, he found that even at the close of seven days no forgetting had taken place.

That our curve follows so closely the relatively simple theoretical formula seems rather remarkable. And upon presenting these results to Professor William E. Story, of the Department of Mathematics, Clark University, we immediately aroused his suspicion that an error had crept in. The present writer, because of lack of space and additional proof, reserves his criticism of the validity of the *Ersparnis-methode* as a measure of the amount forgotten.

The above formulae prove to be rather absurd, at first glance, if a very brief time, a second, for example, is considered. And at the moment when the act of learning is completed, according to the above formulae, an infinitely large negative amount is forgotten. In our own formula, at the close of one-tenth of a minute after the close of the learning period, forgetting begins. This does not appear erroneous if we view it in comparison with the positive "after image" following the presentation of a visual stimulus; and we may probably justly compare this theoretical result with the experimental findings of Wolfe and others, cited above, that the period of greatest accuracy in recognition is not immediately after the stimulus has ceased but about two or three seconds later, after which forgetting immediately proceeds very rapidly.

to be explained from the fact that his observers made a recall when they thought they had learned the series, and then a second recall to establish greater certainty that they actually had it learned. These recalls, being somewhat valuable to the observer as a means of learning, make it very probable that his observers learned each series beyond the point where it was just learned or known, that is, that the series was over-learned in every instance. Now it is unquestionably true that if one learns a series of twelve syllables until it can be reproduced without hesitation in ten seconds, as did Radossawljewitsch's observers, the learning has been more thoroughly done than if one learns it so that he is just able to recall each succeeding syllable in two seconds, as was the case in our experiments.

The whole investigation of this problem is based upon the measurement of learning and relearning, since the ratio of these two measurements is the index of the amount forgotten. In both the learning and the relearning, it is very important that the process shall not be continued beyond the point where the prediction of the forthcoming syllable is barely possible. This secures a two-fold desideratum,—a constant and uniform degree of perfection of learning, and a complete absence of over-learning. Since the ratio of the relearning time to the learning time is the variable<sup>13</sup> which has been adopted as the unit of measurement, the rate of learning, both during the initial act of reading and during the subsequent act of recall (in the investigations of Ebbinghaus and Radossawljewitsch), must be made as uniform as possible; and the other factors must equally be kept as nearly constant as possible. Thus, we must take into account the whole time spent in the process of learning, i.e., the time spent in recalling and trying to recall as well as the time spent in observation. Radossawljewitsch, in measuring the time spent in learning, did not consider at all the value of his double recall. The act of recalling introduces one or other of two causes of error into his method: 1. In recalling after the reading has continued

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<sup>13</sup> Ebbinghaus introduced the plan of measuring the amount forgotten in terms of the time required for relearning, as compared with the time required for initial learning (*Ersparnis-methode*). Müller and Pilzecker (Experimentelle Beiträge zur Lehre vom Gedächtnis. *Zeitschrift für Psych. u. Physiol. d. Sinnesorgane. Ergänzungsband I.* Leipzig, Barth, 1900. 300 pp.) introduced the method of right associates (*Treffermethode*). This latter method measures primarily the strength of the associative bonds; while in the *Ersparnis-methode* it is primarily the retention of non-associated syllables as such, that is measured.

to the point of the observer's ability to reproduce the material, the learning is carried beyond the point of just knowing,—what amount beyond we are unable to determine,—and this vitiates the experiment; 2. and if the observer has not learned the material to the point where he is able to reproduce it, and by a process of recalling and thinking about it is enabled to do so, he has learned by the process of recall. It is therefore erroneous to fail to regard the recall-time as learning-time, and include it in the computations. For this reason, we introduced no pause between successive readings of a series; nor did we allow a period for recall at the end of the act of learning. The reading was continued until each syllable was learned just to the point where it could be reproduced or anticipated during the two seconds before it came into view. Thus the recall factor<sup>14</sup> was at work, but under uni-

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<sup>14</sup> In every act of difficult learning factors of observation and of recall are at work. In observing, the emphasis is placed upon a complete grasping, taking in or noticing what is presented; while in recalling, the emphasis is placed upon a holding or a bringing again to mind of images of the things observed. If only one nonsense syllable has been observed, it may be learned by simply glancing at it; and it may be remembered all day if only it be recalled occasionally. Here the recall factor is, in fact, equivalent to a relearning, and is similar in importance to a re-observing. This is most plainly seen in the case where, for instance, the syllable has apparently been forgotten. By pondering and thinking, by trying to recall the syllable, we may be able to reproduce it, which is just as clearly a relearning of the syllable as though it were observed again. And it may be remembered longer and more vividly if recalled than if re-observed. We have not found it possible to learn twelve syllables by taking a single glance at each. Presentations must recur several times, in fact, about a dozen times; and the recall factor is steadily and keenly active throughout, holding and bringing up again the images. During the later repetitions of a twelve-syllable series, many of the syllables are known,—are present to consciousness as a result of recall,—before they appear in the presentation. The observation factor is less prominent here than it was at the beginning of the learning; and the last repetition is of little value as an observation, because the time is mostly spent in recalling the more difficult syllables. Thus, by holding the attention uniformly upon the learning, we bring it about that the observation and the recall factors work together; and we can measure them together as learning-time. In this way we consider the whole time spent in learning. This same method we used in relearning, which affords us uniformity in learning and also furnishes a more satisfactory measure than either the observation-time alone or the amount recalled would give.

We are not able to correlate the results of the experiments of Bean (C. H. Bean. *The Curve of Forgetting*. *Archives of Psychol.* No. 21, Mar., 1912. 1-45.) with the present findings, because his work was done by the recall method alone. His observers learned only nine consonants, and made several recalls during the relearning, which as one might expect would secure a better and more thorough learning.

form conditions. It was measured in both the learning and the relearning. Since Radossawljewitsch granted to his observers both the pause and the recall, and did not count these as learning-time, and since these are of real value in learning, his results show a greater percentage remembered, as we see from a comparison of the curves. For example, the percentage remembered in his curve at the end of the twenty-four-hour period, is 67.8 as compared with our 57.8.

The effects of practice and familiarity must be taken into account in every memory experiment. It appears that Radossawljewitsch failed to do this. During the first sitting of his whole investigation he made a determination of the amount forgotten at the end of the five-minute period; and his results show that only three per cent. was forgotten. A re-determination, made just one month later, showed that nearly nine per cent. was now forgotten during this five-minute interval,—almost three times as much as the first determination showed. This great retentivity at the outset one would naturally expect, because it is well-known that unfamiliar occurrences are more vividly experienced and are longer remembered than ordinary occurrences, presumably on account of their novelty and enhanced interest. This we found to be true in our experiments. In fact, two months after learning the series which had been presented at the first sitting of our investigation, four of our observers succeeded in recalling it entirely without any difficulty. This

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His curve shows a higher degree of retention than any other investigator has found. In the introductory chapter of his paper he notes the interesting deviation in the curve plotted by Radossawljewitsch. But apparently he has omitted to investigate the eight-hour interval; and the main purpose of his investigation seems to be to find the curve of forgetting as it may be determined by the recall method, for intervals of one day or longer.

In the section of his work which deals with gain in speed and retention of speed in the act of typewriting, there is little relation to our problem. Those observations during the time which we allowed as practice,—preliminary to our experiment,—correspond to his work, since he is interested in measuring the losses during the period of rapid gain in rate of learning. (See the first ten tests in our practice curve on page 22.)

Bean did employ the *Ersparnis-methode*, however, in a very brief series of experiments. Two of his observers learned and relearned certain brief exercises on the typewriter; but by this method only three tests were taken for each period by each observer, and in these tests the number of repetitions for learning was so few as three. His measurements, in terms of number of repetitions during relearning, must necessarily turn out to be either 33.3, 66.6, or 100.0 per cent.,—a very crudely graduated scale.

was not true of the later series, after the task and the method had become familiar to the observers. The inclusion of his initial determinations vitiates the computed curve published by Radossawljewitsch, notwithstanding the fact that he attempted to eliminate the error by an appeal to check experiments.

A more serious defect in method consists in his failure to distribute the learning period of each observer throughout the day. The work of Oehrns,<sup>15</sup> of Pillsbury,<sup>16</sup> Larguier des Bancel's,<sup>17</sup> and particularly that of Ebbinghaus,<sup>18</sup> shows that observers are not able to do mental work equally well at all times of the day. Ebbinghaus found that in his own case the act of learning was accomplished in 12 per cent. less time in the morning than in the latter part of the day.

Table I shows that certain observers did most rapid learning in the morning at eight o'clock, others at eleven in the morning, others at three o'clock in the afternoon, and still others at eight o'clock in the evening. The average of the records of all observers shows that the most rapid work was done in the morning at eight o'clock, the least rapid at five o'clock in the afternoon. This afternoon hour is approximately the period when all of Radossawljewitsch's observers relearned for the eight-hour point in the curve. His plan of having several observers work in the morning, between seven and eleven o'clock, and several in the afternoon, between one and six o'clock, proved to be convenient for all his intervals up to twenty-four hours, excepting for the eight-hour period. Here he shifted the afternoon workers to the morning hours, when, as their learning-times show, they did more rapid work, lowering their time for the learning of a series from 8.2 to 6.6 repetitions (or one-fifth). Consequently, in the case of the eight-hour interval, the relearning was done in the later part of the day, when the observers did less rapid work (thus increasing their relearning-time by one-fourth). In a word, this variation in method, during the progress of his investigation, decreased the learning time by one-fifth, and increased the relearning time by one-fourth, in so far as these shifted

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<sup>15</sup> A. Oehrns. Experimentelle Studien zur Individualpsychologie. (Kraepelin's) *Psychol. Arbeiten*, I, 1896, 92-151.

<sup>16</sup> W. B. Pillsbury. Attention Waves as a Means of Measuring Fatigue. *Am. Jour. of Psychol.* XIV, 1903, 277-288.

<sup>17</sup> J. Larguier des Bancel's. Note sur les variations de la mémoire au cours de la journée, *L'ann. psy.*, VIII, 1901, 204-213.

<sup>18</sup> *Op. cit.*, 95.

observers were concerned.<sup>19</sup> If we add to the learning-time this amount due to error (or subtract it from the relearning-time), we find that Radossawljewitsch's observers then show a forgetting of 44 per cent. after the eight-hour interval instead of the 52 per cent. that he reported. This would smooth out his curve, and eliminate the enormous irregular deviation which is so characteristically present at this point.

If we select from our data those results which were obtained under conditions similar to those of Radossawljewitsch for the eight-hour period, we find that his curve and our modified curve are approximately identical at this point, but that the amount forgotten is slightly greater in the case of our observers. If we choose only those data (the length of time required for initial learning) obtained at the time of day when learning is most efficient for each observer, and if we base our measurement of forgetting upon data obtained eight hours after this most favorable time of day (see line *C* of Table III.), we find, as Radossawljewitsch did, that a relative excess of forgetting has occurred at the end of the eight-hour interval; but if, on the other hand, we arbitrarily select data dealing exclusively with times of day when learning is least rapid (see line *D* Table III.), we find that the curve plotted from these findings deviates in the opposite direction at the end of the eight-hour interval.

An appreciation of all of these considerations convinces one that the enormous deviation which characterizes the eight-hour point in the curve of Radossawljewitsch is not a product of purely memorial factors. It is clearly a product of variable extraneous conditions, chief among which is the variable time of day at which his observers learned and relearned their memorial material. It is a well-known fact that the influence of fatigue, of condition of nourishment, and of other purely physiological processes gives rise to a diurnal variation of mental efficiency. And there seems to be no doubt that the most characteristic finding which Radossawljewitsch obtained in his investigation is to be interpreted, not as a lapse in memorial efficiency indicating that a relative excess of forgetting normally occurs eight hours after learning, but is to be interpreted as a lapse of general mental efficiency which normally occurs toward the close of the day.

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<sup>19</sup> *Op cit.*, 44-47. These figures are obtained from the results of the twelve-syllable series, tables 19-22.

The results of Table III, together with the Radossawlewitsch curve (F) and the Ebbinghaus curve (G) are plotted in Plate II immediately following Table III.

TABLE III. EFFECTS OF THE MORE AND LESS FAVORABLE PERIODS FOR LEARNING, AS SHOWN IN THE RATIO OF RELEARNING-TIME TO LEARNING-TIME

THIS TABLE SHOWS THE EFFECT WHICH IS PRODUCED WHEN THE LEARNING-PERIOD FALLS AT A MORE FAVORABLE TIME OF DAY AND THE RELEARNING-PERIOD AT A LESS FAVORABLE TIME, AND VICE VERSA. THE NUMBERS REPRESENT THE RATIOS (COMPUTED FROM AVERAGES), EXPRESSED IN PER CENTS., OF RELEARNING-TIME TO LEARNING-TIME, WHEN:

- A. The initial learnings were done at all times of day for the determinations of each interval, as in Table II.
- B. The initial learning was done only at 8 A.M.
- C. The initial learning was done at the period of most rapid learning for each observer.
- D. The initial learning was done at the period of least rapid learning for each observer.
- E. The relearning at the close of the eight-hour interval fell at the period of most rapid learning, for each observer.

<i>Interval</i>	<i>Half hr.</i>	<i>1 hr.</i>	<i>2 hr.</i>	<i>4 hr.</i>	<i>8 hr.</i>	<i>12 hr.</i>	<i>16 hr.</i>	<i>24 hr.</i>	<i>36 hr.</i>	<i>48 hr.</i>	<i>72 hr.</i>
A	25.0	27.2	30.6	33.6	34.5	36.2	37.0	42.2	41.2	44.5	47.5
B	19.2	20.9	33.1	36.8	37.1	41.5	....	42.0	39.4	49.0	47.9
C	26.1	21.6	28.5	33.4	56.4	44.7	....	42.5	31.6	44.5	46.5
D	19.8	21.3	22.1	21.3	26.4	42.0	42.0	36.7	33.0	48.3	48.7
E	19.8	26.0	24.3	23.4	25.4	....	....	34.0	42.0	47.0	50.1

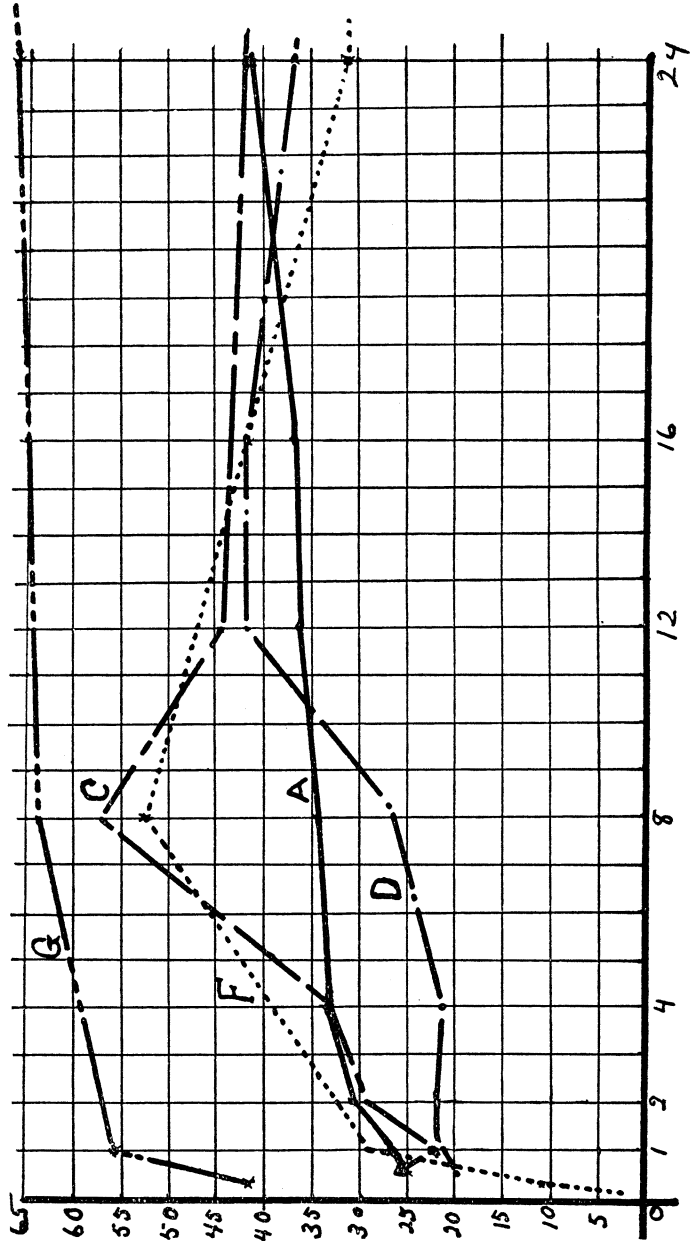
### V. Conclusions

1. The rate of learning increases very rapidly during the first few sittings, then gradually approaches constancy.

2. The rate of learning varies with time of day. In agreement with Ebbinghaus and later investigators, we have found that the most rapid learning is done, by many observers, during the morning hours; of the times of day employed in this investigation, eight o'clock in the morning proved to be, on the average, most favorable, and five o'clock in the afternoon, least favorable for learning.

## PLATE II.—COMPARATIVE CURVES OF FORGETTING, SHOWING THE INFLUENCE OF DIURNAL VARIATION

These curves express, in graphic form, results which appear in Table III, together with the findings of Ebbinghaus (G) and Radossawljewitsch (F). The numbers in the ordinate indicate the amounts forgotten,—expressed in per cents.; the numbers in the abscissa indicate the temporal intervals,—expressed in hours. (In order to avoid excess of detail in this plate we have omitted plotting B and E; the reader may estimate the general form of these curves from the data contained in Table III, p. 22.)



3. The initial and final syllables of a series are the first to be learned, and the central syllables of the series are the last to be learned. This result is in agreement with the findings of former investigators.

4. The order and position of the syllables in a series is recalled with greater accuracy than the syllables themselves. This does not agree with the results of Bean cited earlier in this paper; but his material consisted of nine consonants, while ours consisted of twelve syllables; and the difference between our findings is probably due in part to dissimilarity of material.

5. Absence of free reproduction does not mean complete oblivescence; hence the amount that has been forgotten can not be measured from a determination of the amount that can not voluntarily be recalled. However, the measurement of forgetting made by means of free unaided recall does in some cases correspond somewhat closely with the measurement according to the *Ersparnis-methode*.

6. Our nonsense syllables give rise to few associations with words, except in the case of one observer for whom, in many instances, associations arise involuntarily.

7. The amount of forgetting for this observer is similar to that which Radossawljewitsch found for meaningful material.

8. No one type of imagery is strikingly superior to another as a means of learning or of remembering.

9. Our results do not justify any conclusion regarding the correlation of learning or remembering ability of men and women, because of our limited number of women observers.

10. Rapid learners may remember more than slow learners.

11. The distribution of learning-times throughout the day eliminates from the curve the error which is due to the variable influence of fatigue; failure to control this variable factor is undoubtedly the cause of the enormous deviation at the close of the eight-hour interval in the Radossawljewitsch curve.

12. The curve of forgetting for nonsense syllables in series of twelve, as determined by the lapse of time, is a uniformly progressive curve much as Ebbinghaus found; but under the conditions of our investigation, the progress of forgetting is slower than Ebbinghaus found it to be, and somewhat faster than Radossawljewitsch found.